Differential Effects of Changed Precipitation Patterns on Co-Existing Dominant Species in Inner Mongolia Typical Grassland: Significance for Drought Management

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Differential effects of changed precipitation patterns on co-existing dominant species in Inner Mongolia typical grassland: significance for drought management

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Key words: changed rainfall regimes; water stress; rainfall interval; rainfall frequency; root

Abstract

More extreme precipitation patterns are occurring worldwide in the context of global climate change. These patterns are characterized by larger event size separated by longer within-season drought periods, which are novel climatic conditions to many ecosystems while their consequences are largely unknown. Consequences of changed precipitation patterns on grassland could be complex since the effects of precipitation interval and total precipitation quantity can interact greatly with each other, and can differ among co-existing dominant species. Meanwhile, few researches explored the impacts of changed precipitation patterns on the hidden half – grassland root system. The objective of this study is to explore the responses of co-existing dominant species (*Leymus chinensis* and *Stipa grandis*) of Inner Mongolia typical grassland to changed precipitation pattern. A simulated experiment over the whole growing season (July to September) was conducted in open-top chambers at Inner Mongolia Grassland Ecosystem Research Station of Chinese Academy of Sciences. The research examined the effects of total precipitation quantity and precipitation interval on their aboveground and belowground growth and root/shoot ratio. It was found that precipitation interval was as significant as total precipitation quantity in affecting growth of the two dominant species. Belowground growth of *Leymus chinensis* and *Stipa grandis* responded to changed precipitation patterns in opposite ways, and the effects of total precipitation quantity and precipitation interval depended greatly on each other. It was inferred that precipitation pattern of relatively higher total precipitation quantity and relatively longer precipitation interval would favour growth of *Leymus chinensis*, and precipitation pattern of relatively lower total precipitation quantity and relatively longer precipitation interval would favour for growth of *Stipa grandis*. These differential results provide important insight for drought management strategies in this area in face of future climate change scenarios.

Introduction

As global climate models have predicted and lots of observing and research evidences have confirmed, besides the increasing precipitation quantities on the global level, more extreme precipitation patterns are occurring together with atmospheric warming. Precipitation patterns are predicted to change world-wide in terms of the total precipitation quantity, the precipitation interval and the precipitation quantity of each event (e.g., Meehl et al. 2005). Water is the main limiting factor of grassland ecosystem, while researchers usually pay more attention to the total precipitation quantity but not the change of precipitation pattern. The distribution of rainfall events in a season is important to the growth of plants, such that the frequency and intensity of rainfall events may be both important for regulating plant productivity (Swemmer et al. 2007). The predicted more extreme precipitation patterns, which are characterized by larger event size separated by longer within-season drought periods, are novel climatic conditions to many ecosystem types while influences are largely unknown.

Due to various limitations, few studies on response of grasslands to changed precipitation patterns had put emphasis on the belowground variables, especially for the belowground growth dynamics within growing season. For instance, studies on impacts of changed precipitation pattern on growth of root system and the ratio of root to shoot biomass allocation are limited (Chou et al. 2008).

This study explored the effects of changed precipitation pattern on the above- and below-ground growth and root/shoot ratio of two co-existing dominant species (*Leymus chinensis* and *Stipa grandis*) of Inner Mongolia typical grassland. The objective of this study is to explore their responses to changed precipitation pattern which can provide important insight into responses of Inner Mongolia typical grassland to future changed precipitation patterns in the context of global climate change.

Methods and Study Site

A simulated experiment was conducted on seedlings of *Leymus chinensis* and *Stipa grandis* – two dominant species of Inner Mongolia typical grassland – in open-top chambers at Inner Mongolia Grassland Ecosystem

Research Station of Chinese Academy of Sciences (Figure 1). The duration of treatments was 75 days, from July 16 to September 30, 2009. The study site and experimental procedures were described in Zhou (2010). In brief, the experimental simulation included two total rainfall levels (Q1: 150mm – the average rainfall quantity of the site during the same period in the past 27 years, and Q2: 50% increase in total rainfall – 225mm), two rainfall interval levels (I1: one event every 5 days, and I2: one event every 15 days) and one natural rainfall level during the experiment (the natural rainfall situation outside the OTC in the experiment). The total rainfall gradient and rainfall pattern can be simulated by controlling the single watering amount and watering interval. The four watering scenarios were: (1) Q1I1, the total rainfall was 150 mm, the rainfall interval was 5 days, and plants were watered with 10 mm each time; (2) Q1I2, the total rainfall was 150 mm, the rainfall interval was 15 days, and plants were watered with 30 mm each time; (3) Q2I1, the total rainfall was 225mm, the rainfall interval was 5 days, and plants were watered with 15 mm each time; (4) Q2I2, the total rainfall was 225 mm, the rainfall interval was 15 days, and plants were watered with 45 mm each time. The effects of total precipitation quantity (Q1 and Q2) and precipitation interval (I1 and I2) on aboveground and belowground growth and root/shoot ratio were examined. Differences were tested using a One-Way ANOVA with a Tukey post hoc test of significance.

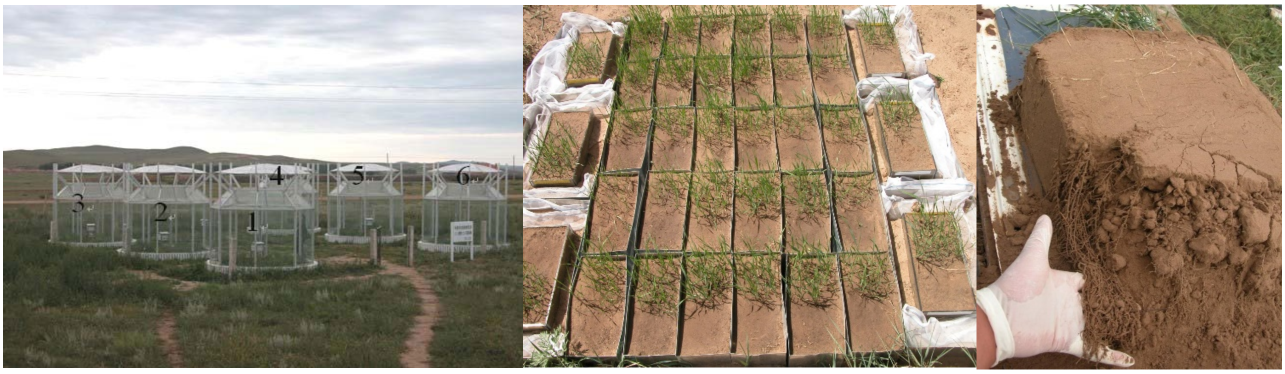

Figure 1. Distribution of six rainfall-sheltered Open top chambers, and location of seedlings in buckets, whose one half was planted with ten plants from the very beginning and the other half did not, allowing root proliferation to the unplanted half bucket area from plants in the planted half bucket area.

Results

At final harvest, aboveground biomass of seedlings of *Leymus chinensis* was increased by an average of 33.9% ($P < 0.05$) by increased total precipitation quantity (+50%) and an average of 31.3% ($P < 0.05$) by extended precipitation interval from 5 days to 15 days (Figure 2). Aboveground biomass of seedlings of *Stipa grandis* was increased by average 23.0% ($P < 0.05$) by increased total precipitation quantity (+50%) and by an average of 48.8% ($P < 0.001$) by extended precipitation interval from 5 days to 15 days (Figure 2).

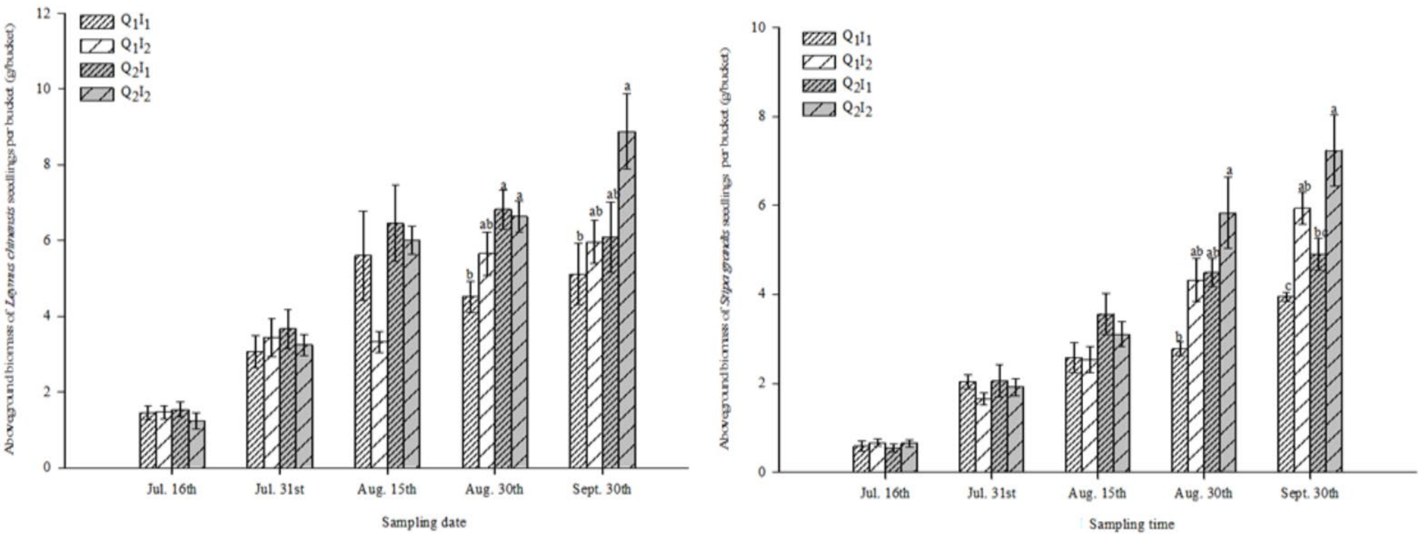

Figure 2. Dynamics of aboveground biomass of seedlings of *Lymus chinensis* and *Stipa grandis* in different precipitation patterns (mean ± SE, n = 5). Significant differences at $P < 0.05$ are indicated by different letters.

When compared with that under low total precipitation quantity with same precipitation interval, root biomass and belowground biomass of seedlings of *Leymus chinensis* were respectively increased by 58.3% ($P < 0.05$) and 62.4% ($P < 0.05$) by increased quantity with long interval, while they were not significant affected by increased quantity with short interval (Figure 3). When compared with that under short precipitation interval with same total precipitation quantity, root biomass and belowground biomass of seedlings of *Leymus chinensis* were respectively increased by 88.7% ($P < 0.001$) and 70.6% ($P < 0.05$) by extended interval with high quantity, while they were not significant affected by extended interval with low quantity (Figure 3). Total precipitation quantity had no significant effect on belowground biomass of seedlings of *Stipa grandis*. When compared with that under short precipitation interval with same quantity, belowground biomass of seedlings of *Stipa grandis* were increased by 56.2% ($P < 0.001$) by extended interval with low quantity, while were not significant affected by extended interval with high quantity (Figure 3).

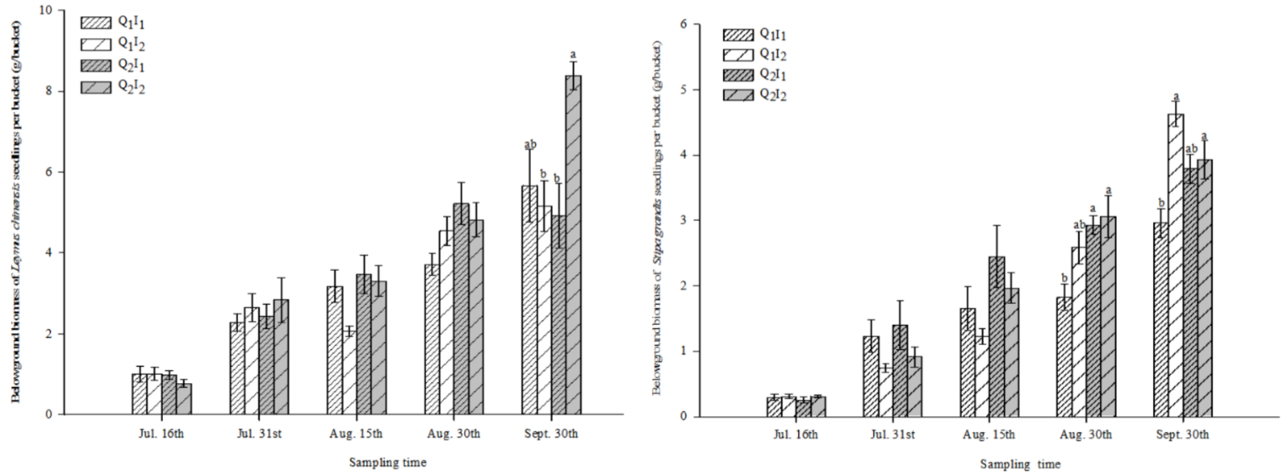

Figure 3. Dynamics of belowground biomass of seedlings of *Lymus chinensis* and *Stipa grandis* in different precipitation patterns (mean ± SE, $n = 5$). Significant differences at $P < 0.05$ are indicated by different letters.

The effect of total precipitation quantity on root/shoot ratio of seedlings of *Leymus chinensis* depended on precipitation interval. Root/shoot ratio was decreased by 28.5% ($P < 0.05$) by increased total precipitation quantity only under short precipitation interval level (Figure 4). The effect of total precipitation quantity and precipitation interval on root/shoot ratio of seedlings of *Stipa grandis* depended greatly on each other. Root/shoot ratio was decreased by 28.4% ($P < 0.05$) by increased total precipitation quantity only under extended precipitation interval level, and decreased by 28.8% ($P < 0.05$) by extended precipitation interval only under increased precipitation quantity level (Figure 4).

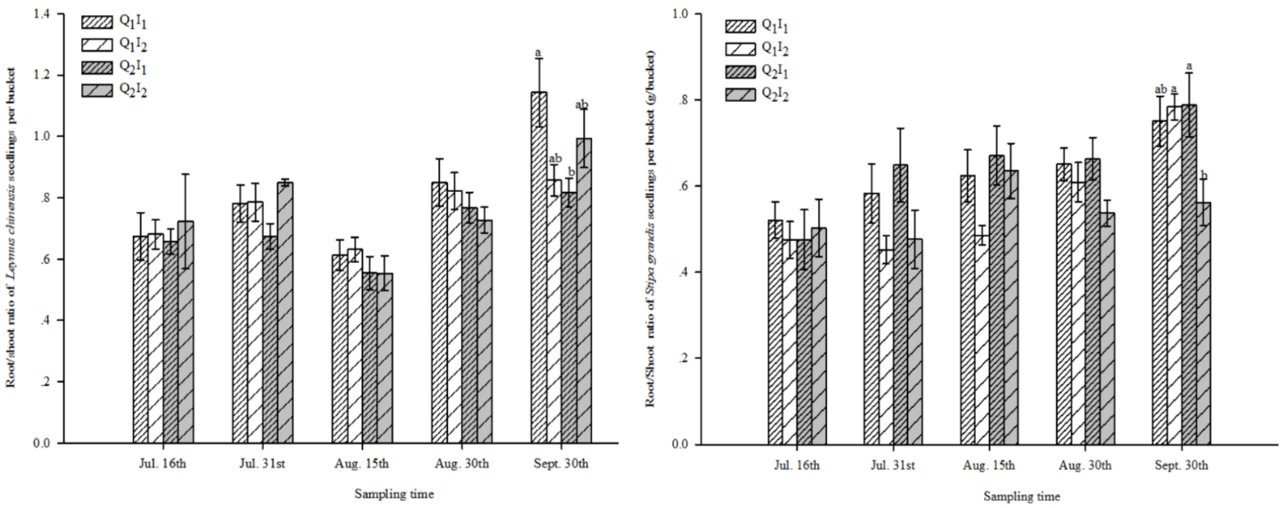

Figure 4. Dynamics of root/shoot ratio of seedlings of *Lymus chinensis* and *Stipa grandis* in different precipitation patterns (mean ± SE, $n = 5$). Significant differences at $P < 0.05$ are indicated by different letters.

During whole treatment period, the differences of aboveground biomass, belowground biomass and total biomass of seedlings of *Leymus chinensis* between treatments for seedlings treated for 30 days and 45 days were determined by total precipitation quantity, while for seedlings treated for 75 days, differences of belowground biomass were determined by precipitation interval, and differences of aboveground biomass and total biomass were co-determined by total precipitation quantity and precipitation interval. The difference in aboveground biomass, belowground biomass and total biomass of seedlings of *Stipa grandis* between treatments for seedlings treated for 30 days and 45 days were determined by total precipitation quantity, while for seedlings treated for 75 days those biomass differences were determined by precipitation interval.

Discussion

It was inferred that precipitation interval could be a key factor as important as total precipitation quantity in affecting growth of seedlings of *Leymus chinensis* and *Stipa grandis* in Inner Mongolia typical grassland. Effects of precipitation pattern on plant growth could be complex since the effect of precipitation interval and total precipitation quantity interacted greatly with each other, and changed with treatment period. Belowground growth of *Leymus chinensis* and *Stipa grandis* responded to changed precipitation patterns in opposite ways while effects of total precipitation quantity and precipitation interval depended greatly on each other. It was predicted that precipitation pattern of relatively high total precipitation quantity and relatively long precipitation interval would do good for growth of *Leymus chinensis*, and precipitation pattern of relatively low total precipitation quantity and relatively long precipitation interval would favour growth of *Stipa grandis*.

The results in this study were based on observations from seedlings of two species for one growing season, which remain to be tested for (1) longer-term responses which could change across seasons and years, (2) species of different climatic origin and/or plant function type (PFT), which could exhibit differential drought sensitivity and acclimation (e.g., Zhou et al. 2016) and (3) responses to co-occurring abiotic and biotic stresses involving changed precipitation pattern. The scaling-up of species-level findings to ecosystem scale would be interesting to understand the response of Inner Mongolia grasslands to changed precipitation patterns more systematically. Changes in plant community composition related to drought response are already beginning to be reported. For instance, the more drought-tolerant *Quercus pubescens* is replacing *Pinus sylvestris* at low altitudes in Switzerland, where recurrent water deficit has been brought about due to climate change (Eilmann et al. 2006). Model-experiment synthesis effort in this area can enhance our predictions of drought consequences on species distributions and vegetation composition on arid and semi-arid ecosystems, particularly in a long-term perspective that takes future climate change scenarios into account (Zhou et al. 2019). Transparent incorporation of the observation-derived PFT-level variation in drought responses into ecosystem models may be necessary. Prospect drought mitigation and adaptation strategies could incorporate the inter-species variation in drought response, which have important implications for management of water-limited ecosystems such as grassland.

Acknowledgements

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References

Chou, W.W., Silver, W.L., Jackson R.D., Thompson, A.W., Allen-Diaz, B. 2008. The sensitivity of annual grassland carbon cycling to the quantity and timing of rainfall. *Global Change Biology,* 14: 1382-1394.

Eilmann, B., Weber, P., Rigling, A., Eckstein, D. 2006. Growth reactions of *Pinus sylvestris* L. and *Quercus pubescens* Willd. to drought years at a xeric site in Valais, Switzerland. *Dendrochronologia*, 23(3): 121-132.

Meehl G.A., Arblaster J.M., Tebaldi C. 2005. Understanding future patterns of increased precipitation intensity in climate model simulations. *Geophysical Research Letters*, 32: L18719.

Swemmer, A.M., Knapp, A.K., Snyman, H.A. 2007. Intra-seasonal precipitation patterns and above-ground productivity in three perennial grasslands. *Journal of Ecology*, 95: 780-788.

Zhou, S. 2010. Effects of changed precipitation patterns on seedlings of two dominant plants (*Leymus chinensis*, *Stipa grandis*) of Inner Mongolia typical grassland, Master thesis, Chinese Academy of Sciences, Beijing.

Zhou, S-X., Medlyn, B.E., Prentice, I.C. 2016. Long-term water stress leads to acclimation of drought sensitivity of photosynthetic capacity in xeric but not riparian *Eucalyptus* species. *Annals of Botany*, 117(1): 133-144.

Zhou, S-X., Prentice, I.C., Medlyn, B.E. 2019. Bridging drought experiment and modeling: representing the differential sensitivities of leaf gas exchange to drought. *Front. Plant Sci.* 9: 1965.